STAFF REPORT

Executive Summary

1997 Global Climate Change

Greenhouse Gas Emissions Reduction Strategies for California Volume 1

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CALIFORNIA ENERGY COMMISSION

Pete Wilson, *Governor*

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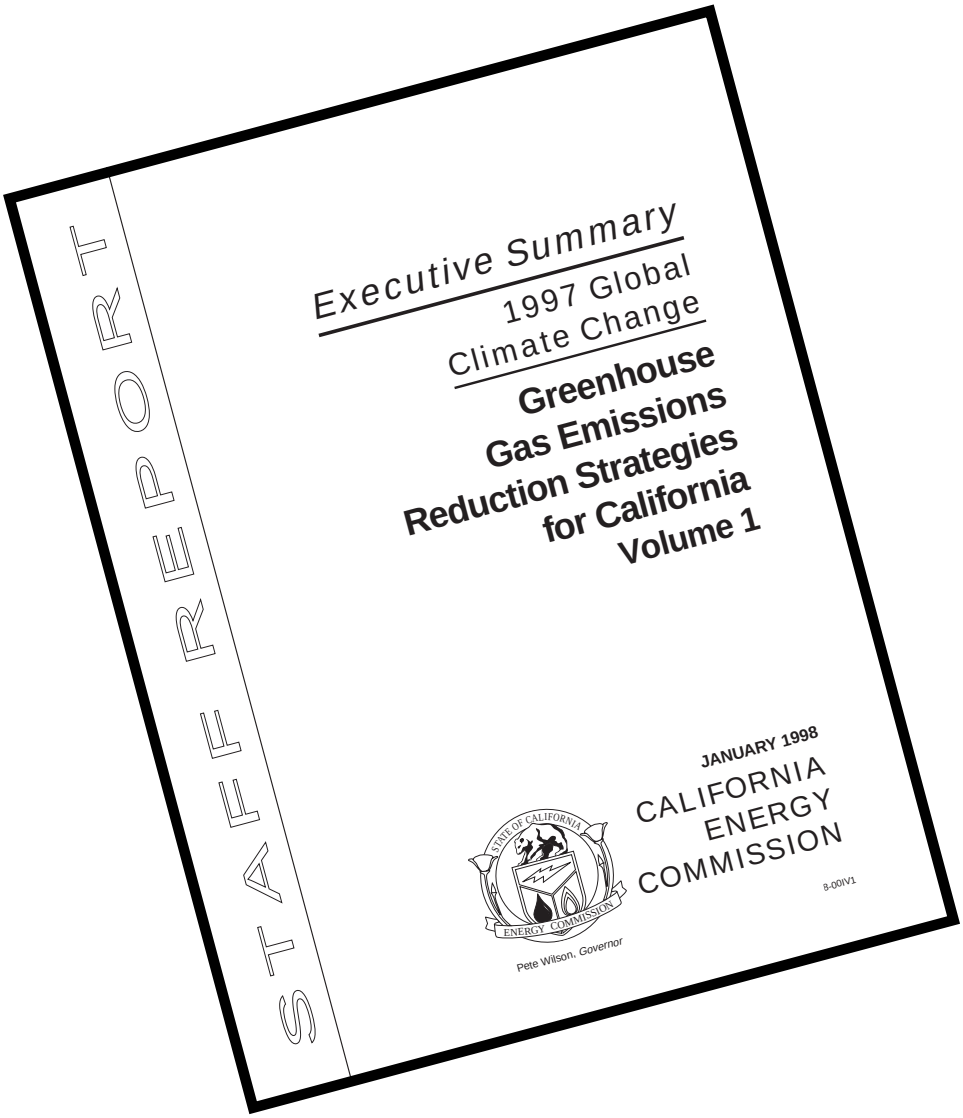

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Introduction

California has led the nation in adopting far-reaching policies to improve energy efficiency, reduce energy costs, and mitigate the adverse impacts on the environment of energy production and use. As well as reducing energy use as a matter of sound economic and environmental policy, the state has substantially reduced emissions that contribute to global climate change, including carbon dioxide and methane. Major state policies have included creating energy-efficient buildings and requiring energy-saving appliances; developing energy-efficient industrial processes; promoting lower-emission alternatives to gasoline and diesel fuel; substantial switching to cleaner natural gas to generate electricity; and researching, developing and commercializing renewable energy resources.

Although some of California's lower energy use is the result of a milder climate and less energy-intensive industries than many other states, it is partly because of these energy policies that California's carbon dioxide (CO_2) emissions are about 40 percent less, per capita, than the national average. In 1994, electricity generation in the state produced a little over 16 percent of all carbon-related emissions, compared with the national average of 39 percent. California's energy policies have been carried out primarily to reduce costs to consumers and air pollution. However, these "no regrets" policies have set California on a firm path to respond effectively to growing concerns about the effects of human-caused greenhouse gas (GHG) emissions on the earth's ecosystem.

California's *1997 Global Climate Change Report: Greenhouse Gas Emissions Reduction Strategies for California* was prepared by the California Energy Commission staff as part of the Federal Environmental Protection Agency's (EPA) partnership with states to develop and evaluate strategies to reduce global climate change effects. California had demonstrated concern about these issues for some time. In 1988, the California Legislature passed legislation (AB 4420, Sher) directing the Energy Commission to study the potential impacts of global climate change trends on the state, including implications for energy supply and demand and impacts on the economy, environment, agriculture, water supplies, and the transportation system. The Commission's report, *1991 Global Climate Change: Potential Impacts and Policy Recommendations*, was adopted by the Commission and submitted to the Governor and Legislature in November, 1991. The report recommended a broad range of policies and strategies for reducing greenhouse gases, including:

1. Promoting energy-efficient technologies and strategies in the residential, commercial and industrial sectors

2. Accounting for environmental externalities in assessing the costs of energy production, resource planning, and procurement

3. Promoting development and integration of renewable generating technologies into the electricity system

4. Promoting high-efficiency gas generation technologies

5. Improving forestry, solid waste and recycling, and livestock management

6. Expanding markets for low-emission alternative fuels and vehicles

7. Promoting research and development on biomass-based alcohol fuels

8. Reducing vehicle miles traveled in personal vehicles, through promoting improved and expanded transportation alternatives, VMT fees, and other highway use fees; and

9. Expanding land use planning to incorporate long-term transportation needs and promote strategies for better management of transportation demand.

Goals of the 1997 California Global Climate Change Report

At the latest Conference of the Parties to the Framework Convention on Climate Change (FCCC), held in Kyoto, Japan in December, 1997, the United States committed to a target of reducing greenhouse gas emissions to 7 percent below 1990 levels, between the years 2008 and 2012. If this commitment is ratified by Congress, the analysis in this report will provide California with a firm basis upon which to further evaluate and adopt effective policies and strategies to reduce greenhouse gas emissions.

The *1997 California Global Climate Change Report* evaluates the state's progress on significant policy recommendations and strategies adopted in the *1991 Report* for all energy-economic sectors, and updates and improves the analyses of strategies to reduce greenhouse gas emissions. The report also discusses the potential effects on energy production and use of recent restructuring of the state's energy supply and services system. Because transportation produces over half (nearly 57 percent) of all of California's CO_2 emissions, the study pays particular attention to transportation strategies that have significant emissions-reducing benefits. The report also looks at economic sectors that produce most of the state's methane, the second most important greenhouse gas, and discusses strategies to decrease its effects.

The analyses presented in this report are based on the updated California emissions inventory for 1991-1994 and projections for the years 2000, 2005 and 2010 (*Historical and Forecasted Greenhouse Gas Emissions Inventories for California*), which serves as Appendix A of the report.

Significant Findings

In evaluating the numerous energy-economic sectors producing greenhouse gases in California, the study found that the most significant reductions in CO_2 emissions, which represent close to 88 percent of all greenhouse gases in the state, can be achieved through
1) continued energy efficiency programs in all sectors, including electricity generation; 2) further developing and integrating renewable energy resources into electricity supplies; and,
3) promoting transportation energy efficiency strategies. Specific strategies were evaluated in each of these areas.

Energy Efficiency in the Residential, Commercial and Industrial Sectors

- Funding energy efficiency programs
- Voluntary industrial sector energy efficiency/GHG emissions reductions programs
- Alternative California oil and natural gas production technologies

Electricity Generation

- Accounting for the costs of environmental externalities in resource planning and procurement
- Promoting high-efficiency gas (HEG) generation technologies

Renewable Energy Resources Development

- Funding renewable resources development and commercialization during transition to a market-driven economy

· Promoting further integration of renewable generation technologies into the electricity system

Transportation Energy Efficiency

· Continued development and promotion of clean, alternative fuel vehicles (AFVs)

· Continued alternative fuel vehicle infrastructure development

· Production and use of biomass to produce transportation fuels

· Pricing measures to reduce VMT

· Higher fuel economy standards

· Alternative fuel vehicle incentives, including fuel subsidies and vehicle purchase incentives

· Vehicle Miles Traveled (VMT) taxes and congestion fees to reduce VMT

· Land use/transportation strategies to reduce congestion, improve air quality and reduce CO_2 emissions

Other Strategies

Strategies to reduce both methane and CO_2 emissions in other economic sectors were also evaluated. For these sectors, the report focuses on improvements in:

· Forestry management for carbon sequestration

· Solid waste management for methane and CO_2 reductions

· Livestock management for methane emissions reductions

Strategies in Significant Areas

1. Energy Efficiency: Residential and Commercial Emissions Reduction Strategies

Anticipated energy savings from energy efficiency programs in California's residential and commercial sectors are one of the major sources for projecting reduced CO_2 emissions in the state. In cooperation with the state's utilities, the Commission has demonstrated over many years that energy efficiency investments can provide a high level of energy services for greatly reduced energy use, and that most investments in energy efficiency have been cost-effective.

Chapter II of this report discusses legislation guiding restructuring of the electric industry in California. AB 1890 (1996) established an independent Energy Efficiency Board (EEB) to oversee development of energy efficiency programs during 1998-2002. The minimum funding for energy efficiency programs for the period is roughly the same as expenditures authorized in 1996 by the Public Utilities Commission. The effects of restructuring the industry on the state's energy efficiency programs are still uncertain; therefore, the following conclusions are somewhat speculative.

For energy efficiency, three scenarios of funding for programs in the residential/commercial sectors, and their impacts on CO_2 emissions, were presented as follows: 1) Constant Funding at 1994 levels, 2) Constant Funding at 1996 levels, and, 3) Decline (in funding levels) After 2000. The tables below also include estimates of emissions if no energy efficiency programs were to be offered during that period.

CO_2 Emissions due to Electricity Demand by Residential and Commercial Customers (Millions of Tons)

SCENARIO	2000	2005	2010
1996 Constant Funding	96	103	110
1994 Constant Funding	96	104	111
Decline After 2002	96	104	113
(No Programs)	100	109	118

The lower emissions forecast by the 1996 Constant Funding and Decline After 2002, scenarios reflect funding requirements for efficiency programs from 1998 - 2002, mandated by legislation in 1996-97 that restructured California's electric utility industry (AB 1890); these levels are higher than many observers expected in 1994. From 2005 to 2010, the expected termination of energy efficiency programs shows an increase of CO_2 emissions to levels above those of the other scenarios.

CO_2 Emissions due to Natural Gas Demand by Residential and Commercial Customers (Millions of Tons)

SCENARIO	2000	2005	2010
1996 Constant Funding	7.2	7.5	7.8
Decline After 2002	7.3	7.6	8.0
(No Programs)	7.4	7.7	8.0

In the previous table, any long-or short-term projections of CO_2 emissions due to natural gas demand are tentative. Given the rapidly changing regulatory environment, only three scenarios were presented --the 1996 Constant Funding Scenario, Decline After 2002 Scenario, and a "No Programs" Scenario.

CO_2 Emissions due to Electricity and Gas Demand by Residential and Commercial Customers (Millions of Tons)

SCENARIO	2000	2005	2010
1996 Constant Funding	103	110	118
1994 Constant Funding	103	112	119
Decline After 2002	103	112	121
(No Programs)	107	117	126

The table above combines and summarizes the previous tables. It shows that all scenarios for 2000 have the same CO_2 emissions, four million tons less than if no programs were in place. However, constant funding at 1996 levels would reduce CO_2 emissions by two million tons more than if program efforts declined after 2002. In 2010, funding at 1996 levels would reduce one million tons more CO_2 than the 1994 scenario, and three million tons more than if programs declined after 2002.

2. Energy Efficiency: Industrial Emissions Reduction Strategies

California's industrial sector, comprised of approximately 50,000 businesses, consumes 25 percent of all electricity and 30 percent of all natural gas in the state. About 1200 (3 percent) of these firms are considered to be large energy users and contribute a substantial amount of carbon dioxide emissions. No regulations currently govern overall industrial CO_2 emissions levels, and existing programs designed to reduce these emissions are largely voluntary.

Conclusions

1. For the short-term, changes in the electric utility structure and services, including potential energy price changes, could produce feelings of uncertainty and reluctance among residential and commercial consumers to participate in any new energy efficiency programs. Significantly declining prices could reduce energy saving investments by industrial and residential customers, delaying continued reductions in CO_2.

2. If the Energy Efficiency Board is successful in its market-transformation efforts over the next four years, long-term prospects are good for significant reductions in energy use through energy efficiency programs and associated reductions in CO_2 emissions.

3. California must continue to evaluate the effects of market transformation on publicly-financed energy efficiency programs in the residential and commercial sectors and to support energy efficiency policies and programs that concurrently reduce energy use and carbon dioxide emissions.

4. Although restructuring the state's energy market has heightened California industry's awareness of the potential to reduce electricity costs, it is difficult to predict industry reaction. Demand for energy efficiency and, consequently, emissions improvements may decrease if energy costs are reduced sufficiently to increase payback periods for efficiency measures. Conversely, industry could both seek alternative, less-costly supplies and adopt energy efficiency measures.

5. Since industrial sector programs to reduce CO_2 have been voluntary, with no set targets for reducing emissions, and also because of the uncertainty surrounding changes in publicly-financed funding for energy efficiency programs, there is no way to predict at this time the extent of GHG emissions reductions that could be achieved with specific strategies.

6. California must continue evaluating the effects of the restructured energy industry, potential energy price changes, and other factors on industrial-sector energy efficiency and evaluate and recommend strategies to reduce GHG emissions in the industrial sector.

2. Electric Generation Emissions Reduction Strategies

California's electric generation sector currently represents a little over 16 percent of CO_2 emissions produced in the state, compared to the national average of 39 percent. This difference is due, in part, to California's 20-year history of effective energy efficiency programs, using natural gas, and promoting renewable energy resources in its electric generation mix. Two major strategies to reduce carbon emissions from electricity generation evaluated in the *1997 GCC Report* are: 1) Accounting for the costs of environmental externalities and incorporating their values in energy resource planning and procurement and, 2) Promoting high-efficiency gas (HEG) generation.

1) Accounting for Environmental Externalities

This report describes the process of accounting for environmental costs by placing a value on the amount of criteria air pollutants and CO_2 emitted. The analysis compared private and social costs, based on resource additions planned by investor-owned utilities in California and their comparative CO_2 emissions. Conclusions reached in the report are consistent with those in the *Electricity Report (ER) '96 Committee Draft Final Report* (June, 1997).

Conclusions

1. Balancing economic, energy, and environmental concerns remains as valid as it was when the Energy Commission was established 25 years ago. These goals can be better served with an approach to environmental policy consistent with a competitive market and with other state and federal regulations affecting the electric generation industry.

2. The most economically-efficient method to balance social costs and benefits in a competitive electricity market is through the use of economic incentives. Incentives help ensure that power plant siting and operations decisions account for environmental costs and promote economic and environmentally-efficient growth throughout the state.

3. Well-designed incentive programs should encompass as many emissions sources as possible. Including only major sources, such as powerplants, may exclude potentially lower-cost emission

reduction opportunities from smaller sources which, in aggregate, contribute a much larger share of emissions.

4. Each source should sustain environmental costs in proportion to the harm from their emissions. When firms bear the total costs of their actions, then power plant siting, operation, and shutdown decisions lead to the most efficient number and types of firms, with appropriate investments in new emissions-reduction strategies.

2) High-Efficiency Gas Generation Technologies

Although California relies far less on oil and gas for electricity generation than many other states, this sector is still a significant contributor to CO_2 emissions. High-efficiency gas (HEG) generation systems can significantly improve fuel efficiency over conventional steam turbine systems, substantially reducing emissions. These systems include combined-cycle conventional gas turbines, advanced gas turbine systems (ATS), chemically-recuperated gas turbine cycle (CRGT), and fuel cell/gas turbine hybrid systems.

Conclusions

1. California should continue to support funding for developing and demonstrating advanced, high-efficiency gas turbine technologies and removing impediments to their commercialization.

2. California should continue to promote replacement of less-efficient and more polluting oil and gas generation facilities with new HEG generation technologies, as well as replacing new fossil fuel power plants with these technologies during repowering.

3) Renewable Energy Resources: Developing and Integrating Renewable Generating Technologies

California has a large and diverse renewable energy resource generation industry. Solid-fuel biomass, geothermal, wind, small hydro, solar, landfill gas, digester gas and municipal solid waste facilities produced slightly over 29,000 GWh and 11 percent of the electricity used in the state in 1996. The California Energy Commission has strongly promoted the development and integration of renewable generation technologies into the electricity system. Further, electric utility industry restructuring legislation (AB 1890, 1996) continues to ensure that a high percentage of new generation will come from renewable resources in the future.

In evaluating the potential for renewable energy resources, the Energy Commission believes that, overall, their continued development and use could significantly reduce greenhouse gases. So far, this evaluation has showed that there will probably be little reduction from the base case presented in the Commission's *1994 Electricity Report.* Further analysis is needed on the potential effects on GHGs of renewable resources. Without considering cost-effectiveness or potential electricity and non-electricity system interactions, the various renewable resource options can generally be ranked, based only on CO_2 emissions produced by combustion, as follows:

Rank 1: **Non-GHG Emission Producers:** Wind, hydro, photovoltaics, nuclear, non-gas solar, liquid geothermal (with gas injection)

Rank 2: **Minor GHG Emission Producers**: Gas-assisted solar (no more than 25% gas burn); steam geothermal; biomass (feedstock combusted alternatively); landfill gas (feedstock flared or combusted alternatively); municipal solid waste (MSW) (avoided methane flared or combusted alternatively)

Advanced natural gas power plants would fall slightly below Rank 2, with older-style gas plants close to a "Rank 3," and coal and oil facilities at the bottom of the list.

Conclusions

1. Under restructuring, the level of renewable resources used in the electric generation sector is not expected to differ substantially from renewables additions planned by the utilities in 1994. Comparing available peak capacity from renewables projected for the year 2005 with the 1994 base case (which is based on resources planned under regulatory proceedings) shows a total of 3,520 MW, while the case with AB 1890 policies shows a total of 3,440 MW.

2. While nurturing the growth of California's renewable resources in California remains a strong GHG reduction strategy, consideration must be given to the varying emissions levels and associated costs of different types of renewables when evaluating their effects.

3. Generally, when based solely on CO_2 emissions reductions from electricity generation, renewable resources are preferable to traditional fossil fuels.

4. The Commission staff will continue to evaluate the impacts of renewable resource additions on reducing GHGs in California. Further analysis will factor in cost-effectiveness, extending to societal cost/benefits, to develop a more accurate ranking of renewable energy supply options with regard to GHG emissions.

4. Transportation Efficiency Strategies

Transportation produces nearly 57 percent of all carbon dioxide emissions in the state. Carbon dioxide is directly proportional to the amount of fuel consumed -- every gallon of gasoline burned produces 20 lbs of CO_2, and fuel refining produces additional emissions. The *1991 Global Climate Change Report* contained numerous policy recommendations for reducing emissions of CO_2 from California's transportation sector, including developing alternative (low-emission) fuels, vehicles and markets; promoting biomass-based alcohol fuels; reducing vehicle miles traveled (VMT) by personal vehicles; increasing vehicle fuel efficiency; increasing non-highway transportation efficiency; and incorporating long-term transportation needs into land use planning. The 1997 report further examines strategies relating to these policies and analyzes potential emission reductions associated with a variety of transportation strategies.

1) Alternative Fuel Vehicles

The *1997 GCC Report* discusses alternative fuel vehicles (AFVs) as a major strategy for reducing California's GHG emissions. The report focuses on 1) the current status and outlook for AFV technologies, 2) comparative GHG impacts of AFVs and conventionally-fueled vehicles, and, 3) potential actions to benefit from emissions reductions offered by AFVs. AFV technologies evaluated include alcohol-fuels (methanol and ethanol), natural gas, propane, hydrogen, all electric, and hybrid-electric vehicles. The report also examines two strategies currently underway to promote promising alternative vehicles and fuels:
1) alternative fuel vehicle infrastructure development; and, 2) support for producing biomass as transportation fuel.

Conclusions

1. Methanol: Further advancement of methanol as a strategy for reducing transportation sources of carbon would require additional progress in: 1) developing methanol production options using renewable resources to replace natural gas as the primary feedstock and to forestall the methanol-from-coal option; 2) re-emphasizing dedicated methanol vehicle technology, so that methanol can fully substitute for gasoline in vehicles; and, 3) further developing technologies to efficiently substitute methanol in heavy-duty highway and non-highway applications.

2. Ethanol: Successful development of ethanol processes that minimize fossil fuel inputs, and achieve continual recycling of carbon between combustion and biomass-based production, would be required to achieve the full potential of ethanol fuels for CO_2 emissions reduction.

3. Natural Gas: Additional actions to fully capture the carbon-reducing potential of natural gas as a transportation fuel include: 1) more effectively controlling methane emissions associated with natural gas production and use; 2) continuing to develop more efficient natural gas engine technologies, and more efficient, less-costly fuel storage and refueling systems; and, 3) exploring and developing natural gas use in transportation applications other than highway vehicles.

4. Propane (Liquified Petroleum Gas, LPG): Measures to realize more of the possible benefits associated with this fuel should include: 1) expanding LPG vehicle availability from auto makers and establishing a viable LPG vehicle conversion industry; 2) pursuing a range of options for expanding LPG supplies from domestic and foreign natural gas production, refinery production, and use of excess butanes; and, 3) developing more efficient LPG engine technologies.

5. Hydrogen: For hydrogen fuel to reach its potential, major progress is necessary on producing it economically. Research and development efforts to improve the efficiency and reduce the cost of hydrogen production, using renewable energy sources, are the key to reaching hydrogen's potential for commercialization as a zero-carbon-emitting fuel.

6. Electricity: If California's zero-emission vehicle (ZEV) regulations are successful, electric vehicles (EVs) would become the most prevalent type of AFV on the state's roads and could reach a population of one million vehicles ten years after the regulations are in place. Beyond measures to ensure that the ZEV regulations succeed as designed, other actions that could increase carbon emission reductions achievable with EVs include:

1) Adding new non-fossil fueled electric generating facilities, possibly as a result of California's recent initiative to ensure R&D funding over the next several years for such technologies.

2) Installing more efficient natural gas-fueled generation units, in order to raise the operating efficiency of the electricity supply system enough to increase the CO_2 benefit of EVs.

3) Making improvements in the operating efficiencies of EV technologies, which could make EVs more effective in reducing CO_2 emissions.

2) Alternative Fuel Vehicle Infrastructure

The Commission will continue to carry out the recommendations presented in the *Calfuels Plan: Developing an Infrastructure Plan for Alternative Fuel Vehicles* (1994) to develop the necessary infrastructure for alternative fuel vehicles.

3) Biomass Fuels

The Commission should continue to promote coordinated statewide efforts on research, development, demonstration and commercialization of cost-effective biomass-to-alcohol fuel technologies.

4) Pricing Strategies - Reducing Vehicle Miles Traveled (VMT), Increasing Fuel Efficiency, and Increasing User Fees

The report evaluates transportation pricing strategies for reducing vehicle miles traveled (VMT) and increasing fuel efficiency and briefly discusses the possible effects of increased transit use and high-occupancy vehicle (HOV) lanes. Evaluations of the effects of various pricing strategies on reducing CO_2 emissions from transportation show the following:

1. Fuel/Carbon Taxes

No pricing strategy to reduce greenhouse gases from light-duty (personal) vehicles would be more effective than a carbon tax on each unit of fuel purchased. Averages of carbon emissions by fuel type forecasted for 2010 are based on the base case forecast for all likely fuels. Carbon emissions for electricity were analyzed by the Commission's Electricity Resource Assessment Office and represent incremental power plant system emissions caused by electric vehicle use. Expected carbon percentage reductions for the year 2010 assume an 11 cents per gallon carbon tax.

Prcentage Reduction in Carbon Emissions in 2010 from CALCARS* Simulations of Carbon Tax Relative to Base Case

	Tax Scenarios	
Fuel Scenario	**State Only**	**Nationwide**
Gasoline Only	0.90%	1.39%
All Fuels	0.96%	1.44%

SOURCE: California Conventional and Alternative Fuel Response Simulator Model (CALCARS), documented in the CEC Staff Report, CALCARS: The California Conventional and Alternative Fuel Response Simulator, P 96-003, April, 1996.

2. Other Pricing Strategies

The table below shows the net social benefits and percentage of carbon reductions for various other pricing measures.

Various Pricing Measures Analyzed Relative to the Base Forecast

Case	Net Benefits (1992 $million)	Percent Carbon Reduction
50 Cent Higher Fuel Tax (nationwide)	1,435	14.5
50 Cent Higher Fuel Tax (state-only)	1,433	7.8
40 Cent Higher Fuel Tax (state-only)	1,246	6.2
20 Cent Higher Fuel Tax (nationwide)	901	9.3
20 Cent Higher Fuel Tax (state-only)	719	.8
Higher Fuel Economy	318	7.9

SOURCE: 1993-94 California Transportation Energy Analysis Report

Conclusions

1. Based on pure economic theory, fuel taxes based on carbon content are the most efficient pricing strategy, since they target greenhouse gases directly.

2. Because of the national/international nature of auto manufacturing, nationwide fuel taxes and feebates would reduce carbon emissions by a greater amount than state-only taxes and feebates of the same magnitude.

3. Pricing measures and higher fuel economy standards and feebates appear effective as measures to reduce carbon emissions. HOV lanes and transit use may have to be expanded, and monetary incentives for alternative fuel vehicles combined with pricing measures, for these measures to be truly effective.

4. Fuel taxes and congestion fees could offer significant social benefits, since they reduce congestion and other driving effects, in addition to carbon emissions. Studies on whether these pricing measures are regressive are inconclusive.

5. Although state-only feebates reduce consumer surplus, they do not appear to affect equity adversely. Further, feebates more effectively promote the demand for alternative fuel vehicles than carbon taxes, for a given level of carbon reduction. Feebates do not appear to reduce driving and, therefore, may not offer the high social benefits of pricing measures. In addition, state-only feebates that increase fuel efficiency may not be allowed by the federal government.

6. Nationwide feebates and higher fuel economy standards appear to reduce carbon emissions and to increase consumer surplus for drivers. These policies, though, reduce the average costs of driving, and as a result may actually increase VMT and the external costs related to driving.

7. Subsidies for alternative fuels would probably have to be accompanied by increased gasoline taxes in order to show an overall decline in carbon emissions.

5. Land Use and Transportation Planning

California's unprecedented suburban growth over the past two decades has been the primary cause of the demand for increased transportation services. Mixed-use (neotraditional), transit-oriented development and providing a balance between jobs and housing are two major strategies that have been pursued to directly change land development patterns. These strategies are designed to reduce VMT, congestion and criteria air pollutants and, concurrently, reduce CO_2 emissions. Findings on the potential effectiveness of these strategies in reducing private vehicle trips have not lead to any firm conclusions. Nevertheless, it is essential that California continue to support land development patterns that reduce the economic and environmental costs to the state of using personal vehicles.

Conclusions

1. California's land development trends make it essential for regional and local governments to plan more effectively to meet long-term transportation needs, in ways that will reduce congestion, improve air quality, and reduce CO_2 emissions.

2. California will continue to support a wide variety of transportation strategies to reduce both criteria pollutants and CO_2 emissions. These strategies must be specifically keyed to the individual transportation needs of each region of the state.

3. Results are mixed on the effectiveness of regulations, programs and measures to reduce personal vehicle use, numbers of vehicle trips, VMT, and traffic congestion. The impact of each of these separate strategies may also be slight, which suggests that the state must continue to pursue combinations of the most effective strategies to reduce both harmful air pollutants and CO_2.

4. California should develop an integrated approach to evaluating the effectiveness, costs and benefits of a variety of transportation strategies in reducing congestion, criteria air pollutants and carbon dioxide emissions.

Summary Discussion and Conclusions for Other Sectors

1. Alternative California Oil and Natural Gas Production Technologies

While oil and natural gas production are not a large overall producer of CO_2 emissions in California, traditional production technologies are responsible for about 20 percent of all of the state's industrial CO_2 emissions. Traditional thermal enhanced oil recovery (TEOR) burns up about one barrel of oil for every three barrels produced. Some new oil recovery technologies have the potential to reduce GHG emissions, but strategies to enhance oil and gas recovery have focused on economics alone. Chemical enhanced oil recovery (CEOR, also known as chemical flooding) and gas displacement are two methods that show significant commercial potential for recovering oil from known reservoirs without producing as much CO_2 as traditional methods.

Conclusions

1. Further research and development on cost-effective CEOR processes, such as polymer and surfactant flooding, and improved oil prices, are the keys to successful commercialization of CEOR.

2. Gas displacement enhanced oil recovery results in sequestering carbon dioxide so that no net CO_2 is produced. In gas displacement EOR, injecting carbon dioxide from fossil fuels is currently considered an acceptable, but costly, option for reducing carbon emissions. Existing ammonia manufacturing and coal gasification plants produce cleaner CO_2 that can be used directly for enhanced oil recovery. The Energy Commission should promote making gas displacement

technology more cost-effective and reducing CO_2 emissions by encouraging power producers to work with the oil and gas industry to use these existing resources effectively.

2. Forestry Management for Carbon Sequestration and Emissions Reductions

Forests absorb CO_2 from the atmosphere and store it over a period of time, eventually releasing it back into the atmosphere when organic material burns or decays. Reducing forested areas is greatly increasing the amount of carbon dioxide on earth and amplifying the "greenhouse effect." This report discusses the substantial potential for improving forestry management, including urban forestry practices, to reduce carbon dioxide emissions. The California Department of Forestry and Fire Protection (DFFP) provided the Commission with valuable information on forestry practices that can promote carbon sequestering and also provide other benefits.

Conclusions

1) The DFFP should continue to carry out policies and institutional changes related to the management of wildlands, including expanding and improving the California Forest Incentive Program, which promotes planting trees as a method of removing CO_2 from the atmosphere.

2) The Department should further develop agroforestry and biomass-to-energy programs and reinstate a Statewide Biomass Program to stimulate interest and investment in biomass production and use. Pilot projects should be developed and incentives should be provided to make biomass more economical.

3) Urban trees can be 15 times more effective in reducing carbon dioxide than trees in forests, because they reduce heat islands in urban areas and energy use for cooling. New strategies should be developed to make Urban Tree Planting Programs more widespread and effective, particularly on publicly-held land near or in urban centers.

4) The DFFP should continue to work with the California Energy Commission to develop and evaluate the potential for improved forestry management strategies to contribute to reducing CO_2 emissions.

3. Solid Waste Management for Methane/CO_2 Reductions

Methane is the second most important greenhouse gas contributing to global climate change. Although methane is expected to be only about 10 percent of total greenhouse gas emissions early in the next century, it has 21 times the global climate change effects of CO_2. Oil and natural

gas production, water treatment and fossil fuel combustion all produce some methane, but 90 percent is produced from solid waste landfills and by livestock. Municipal landfill solid waste is the largest source of methane emissions in the state, contributing over 1.4 million tons in 1994, and also a small amount of CO_2 emissions. Over 64 percent of all methane emissions are expected to come from California's landfills by 2010.

The California Integrated Waste Management Board (CIWMB) develops and regulates the state's solid waste management practices. Over the past 10 years, California has been very successful in its landfill management practices. California's Integrated Waste Management Act of 1989 resulted in reducing 25 percent of its landfill, by 1995, through improved solid waste management and gas collection practices that 1) reduced sources of emissions,
2) recycled and composted solid waste and, 3) transformed or disposed of solid waste in landfills. The new target, for the year 2000, is to reduce landfill by 50 percent.

Conclusions

1. The Energy Commission will continue to support the CIWMB in its efforts to meet California's goal of 50 percent landfill diversion by 2000.

2. California state government should analyze the cost-effectiveness of a variety of strategies currently being implemented to manage municipal solid waste. A life-cycle cost analysis, similar to the analysis done by EPA on a national level, should be carried out to determine the costs and benefits associated with each solid waste management strategy California is undertaking.

3. Market analysis should be conducted to estimate revenues to California from the sale of marketable materials resulting from methane source reduction and recycling. This market analysis must, at the very least, be done for source reduction and recycling options. Additional market analyses should be done to determine the potential for electric generation from the combustion of municipal solid waste or landfill gas.

4. As a result of AB 1890, more biomass, municipal solid waste, and land-fill gas projects are expected to be built and be competitive in California's electric industry. The IWMB should continue to monitor criteria and GHG emissions from waste-based electricity production facilities, work with air quality agencies to reduce these emissions, and develop methods to ensure that those who produce waste materials, or benefit from their removal, pay their fair share of the costs of waste disposal through electricity generation. Ratepayers should pay for the cost of power from which they benefit, but not the producer's cost for producing electricity.

4. Livestock Management for Methane Emissions Reductions

About 35 percent of all methane in California is produced by livestock digestive processes, and manure management practices also produce methane; together, these sources produced about 700,000 tons in 1994. California has a large livestock population, which is not expected to change significantly into the next century. While methane production from livestock can be somewhat decreased by using higher-quality feed, the most effective strategies for reducing methane currently focus on improving manure management practices. Methane from manure can be successfully captured and used, through "biogas" technologies, to generate energy.

The two major strategies for reducing methane emissions discussed in the *1997 GCC Report* are
1) encouraging the recovery and collection of methane from livestock waste; and,
2) determining the effectiveness of different methane recovery systems in reducing methane emissions.

Conclusions

1. Further work is required to develop, commercialize and package off-the-shelf systems for small-scale anaerobic fermentation of manure to produce biogas.

2. The Energy Commission should continue to support research, development, demonstration and evaluation of technologies capable of effectively recovering and using methane generated from livestock and other organic waste.

Summary

California will continue to improve its environmental quality and economy by promoting cost-effective, statewide energy-efficient policies and strategies. Strategies adopted should simultaneously increase energy efficiency, reduce petroleum use, improve air quality and reduce the potential effects of greenhouse gas emissions on the state, and on the nation. Because of its past and current energy policies, California is already on the leading edge of efforts to reduce greenhouse gases. These policies have resulted in energy-efficient buildings and appliances, the use of natural gas to replace oil and coal, substantial development of renewable energy resources, promotion of alternative fuel vehicles and infrastructure, and other cost-effective energy strategies.

Further analysis is needed on the effects of specific strategies in reducing greenhouse gases in all areas, including their costs and emissions-reduction potential, to enable California policy-makers

to continue to adopt energy policies that will ensure a robust economy and a beneficial environment for its citizens.